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*Declaration*

*I, Michihiko Matsuba, President of Fukuyama Sangyo Honyaku Center, Ltd., of 16-3, 2-chome, Nogami-cho, Fukuyama, Japan, do solemnly and sincerely declare that I understand well both the Japanese and English languages and that the attached document in English is a full and faithful translation, of the copy of Japanese Unexamined Patent No. Hei-8-300725 laid open on November 19, 1996.*



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MULTI-BEAM SCANNING OPTICAL APPARATUS

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Applicant: Minolta Co., Ltd.

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SPECIFICATION

[TITLE OF THE INVENTION]

Multi-beam scanning optical apparatus

[ABSTRACT]

[Object] To decrease a relative-position error of two spots formed on a to-be-scanned surface by two laser beams in a multi-beam scanning optical apparatus in which scanning is performed by using two laser beams simultaneously and in parallel.

[Solution means] Light source devices A and B are formed by making respective blocks of laser generating devices 1 and 1' and collimator lenses 2 and 2'. In addition, an insulating

member 30 is placed between the optical source device B for outputting a laser beam that permeates a beam splitter 3 and a base plate 27, and both are fixed by means of a resin screw 31.

[WHAT IS CLAIMED IS;]

[Claim 1] A multi-beam scanning optical apparatus comprising:

first and second laser generating devices for emitting a laser beam to scan a to-be-scanned surface;

an optical member that reflects a laser beam emitted from the first laser generating device, that transmits a laser beam emitted from the second laser generating device, and that outputs the two laser beams in parallel; and

an electroconductive base plate on which the first and second laser generating devices and the optical member are mounted;

the multi-beam scanning optical apparatus wherein:

the first and second laser generating devices are constructed so as to reach an operable state by supplying their respective housings with power-supply voltage, and the first laser generating device is attached directly to the electroconductive base plate whereas the second laser generating device is attached to the electroconductive base

plate with an insulating member therebetween.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Invention] The present invention relates to a laser beam scanning optical apparatus used as a writing optical system for use in an LBP (laser beam printer) or a digital PPC (plain paper copier), and, particularly, to a multi-beam scanning optical apparatus for simultaneously scanning a plurality of lines in parallel by use of a plurality of laser beams.

[0002]

[Prior Arts] Conventionally, in the field of laser beam scanning optical apparatuses, use has been made of a multi-beam scanning optical apparatus in which the scanning speed in a sub-scanning direction is made higher by using two laser beams than in a case where one laser beam is used or in which the density of images formed on a to-be-scanned surface is increased by scanning a single scanning line with two laser beams successively and repeatedly.

[0003] Additionally, recently, since images formed by a laser beam scanning optical apparatus have been required to have high resolution, the resolution has been improved by using two laser beams and by halving an interval between scanning lines while

the same speed of image formation is being maintained, in comparison with a case where one laser beam is used.

[0004] These multi-beam scanning optical apparatuses have two laser generating devices in which a laser diode and a photodiode to monitor the quantity of light are contained in an electroconductive housing. Two among four electrodes in total, i.e., two electrodes among an anode and cathode of the laser diode and an anode and cathode of the photodiode are connected together inside the laser generating device, and these are electrically connected to the housing.

[0005] For example, a circuit structure as shown in Fig. 10 is formed when a laser generating device of a type that uses a housing voltage for both an anode of a laser diode LD and a cathode of a photodiode PD is used as a light source of the multi-beam scanning optical apparatus as in Fig. 9. Herein, 1 and 1' each designate the laser generating device. Positive power-supply voltages +B1 and +B2 are applied to housings 301 and 302, respectively.

[0006] In this case, +B1 and +B2 must be the same value, but, in practice, laser diodes LD<sub>1</sub> and LD<sub>2</sub> need to be individually adjusted because of, for example, variations in emission intensity between the laser diodes LD<sub>1</sub> and LD<sub>2</sub>, and, as a result, the power-supply voltage (case voltage) of the laser generating

device 1 and that of the laser generating device 1' are not always the same. Therefore, when the two laser generating devices 1 and 1' are mounted on a single electroconductive base plate, both need to be insulated from each other. Additionally, since there is a fear that a noise will be transmitted from one of the power sources to the other one through the electroconductive base plate irrespective of whether the case voltages (i.e., power-supply voltages) are the same or different in value, it is desirable to insulate both from each other from the viewpoint that both should cut off the influence of this noise.

[0007] Fig. 11 is a top view showing a conventional laser generating device and the structure of its periphery. This part is formed by mounting laser holding members 307 and 307' that hold the laser generating devices 1 and 1', collimator lenses 303 and 303' that make laser beams parallel light beams, a beam splitter 304 that transmits one of the laser beams, that reflects the other laser beam, and that arranges the two laser beams in parallel, etc., on a base plate 306.

[0008] Since error sensitivity is very high to the position of spots that a laser beam forms on a to-be-scanned surface through a scanning optical system, the laser generating devices 1 and 1' and the collimator lenses 303 and 303' are positioned

with high accuracy, and, accordingly, the base plate 306 and the laser holding members 307 and 307' are made of metal and are electrically conductive. The laser generating devices 1 and 1' are insulated from each other by interposing insulating members 305 and 305' between the laser holding members 307 and 307' and the base plate 306, respectively.

[0009]

[Problems to be Solved by the Invention] However, in the prior art shown in Fig. 11, since the insulating members 305 and 305' are interposed between the laser generating devices 1 and 1' and the corresponding collimator lenses 303 and 303', the insulating members 305 and 305' undergo thermal strain caused by heat generation of the laser generating devices 1 and 1' or deformation caused by an external force. Thereby, even when a positional deviation only slightly occurs in the laser generating devices 1 and 1' in planes perpendicular to the respective optical axes of the collimator lenses 303 and 303', laser beams that have passed through the collimator lenses 303 and 303' and that have been output from the beam splitter 304 vary in their slants, and, as a result, an error occurs in the position of spots formed on a to-be-scanned surface by the laser beams.

[0010] In such a situation, in a scanning optical system that

uses one laser beam, no problem arises in the quality of images even if the position error of spots reaches 0.5mm, but, in a multi-beam scanning optical apparatus to which the present invention is applied, the allowance of a relative-position error of two spots by two laser beams is about 1/4 of a dot pitch. That is, since the dot pitch is 63.5 $\mu$ m when the dot density is 400dpi, a barely visible influence appears when a relative-position error of about 10 $\mu$ m occurs. According to the prior art mentioned above, there is a conventional problem in that a time-dependent relative-position error of two spots on the to-be-scanned surface easily exceeds 10 $\mu$ m, so that an image quality is markedly lowered.

[0011] The present invention has been made to solve this problem, and it is an object to provide a multi-beam scanning optical apparatus capable of being controlled so that a relative-position error of two spots formed on a to-be-scanned surface by two laser beams is small even if insulating members that are interposed between two laser generating devices and an electroconductive base plate in order to insulate the two laser generating devices from each other are deformed with the lapse of time so that the position of each laser generating device deviates.

[0012]

[Means for Solving the Problems] To achieve the aforementioned object, in the present invention, a multi-beam scanning optical apparatus comprises first and second laser generating devices for emitting a laser beam to scan a to-be-scanned surface; an optical member that reflects a laser beam emitted from the first laser generating device, that transmits a laser beam emitted from the second laser generating device, and that outputs the two laser beams in parallel; and an electroconductive base plate on which the first and second laser generating devices and the optical member are mounted; wherein the first and second laser generating devices are constructed so as to reach an operable state by supplying their respective housings with power-supply voltage, and the first laser generating device is attached directly to the electroconductive base plate whereas the second laser generating device is attached to the electroconductive base plate with an insulating member therebetween.

[0013]

[Action] Therefore, according to the present invention, for example, when the apparatus is used in such a manner that an anode of a laser diode is connected to an electrically conductive housing, and power-supply voltage is received at the anode from the outside through this housing, a case of the

first laser generating device and a case of the second laser generating device are electrically isolated from each other by the insulating member even in a state of being attached to the electroconductive base plate. Moreover, since the insulating member interposed for insulation is disposed on the side of the second laser generating device (laser generating device on the side where a generated laser beam is transmitted by an optical member), a displacement, which results from interposing the insulating member, in a direction in which the laser beam is propagated is relatively small. That is, even when the insulating member is deformed because of, for example, heat generation of the laser generating device or even when the optical member is displaced, a displacement in a direction in which a laser beam emitted from the optical member is propagated becomes smaller than when the insulating member is disposed on the side of the first laser generating device (laser generating device on the side where a generated laser beam is reflected by an optical member).

[0014]

[Preferred Embodiment of the Invention] Embodiments of a multi-beam scanning optical apparatus to which the present invention is applied will be hereinafter described with reference to the drawings. Fig. 1 is a top view of the

multi-beam scanning optical apparatus according to a first embodiment of the present invention, and Fig. 2 is a partially enlarged view showing laser generating devices 1 and 1', collimator lenses 2 and 2', a beam splitter 3, a base plate 27 on which these are mounted, etc., which are taken from the apparatus. Fig. 2(a) and Fig. 2(b) are a top view and a front view, respectively, of this part.

[0015] Since this multi-beam scanning optical apparatus is required to have high accuracy, and since the accuracy must be kept stable with the lapse of time, a structure is employed in which a mounting base plate 9, which is made of metal and is electrically conductive, is used, and various optical components described later are attached by means of screws 10. Additionally, a counterbored hole 11 to attach the multi-beam scanning optical apparatus to a device body, such as a printer or a copier, is formed in the mounting base plate 9. Since the positional deviation of the laser generating devices 1 and 1', the collimator lenses 2 and 2', and the beam splitter 3 is highly sensitive to the position error of spots formed on a to-be-scanned surface by laser beams through a scanning optical system, a base plate 27 is also made of metal and is electrically conductive in order to guarantee high accuracy.

[0016] In this embodiment, the "optical member" corresponds

to the beam splitter 3.

[0017] Laser beams emitted from the laser generating devices 1 and 1' are converted into parallel light beams by the collimator lenses 2 and 2', respectively, and are made incident in the beam splitter 3. The laser beam emitted from the laser generating device 1 is reflected by an interference film 3a provided in the beam splitter 3, whereas the laser beam emitted from the laser generating device 1' permeates it, and then these two laser beams travel in parallel with the optical axis of the optical system.

[0018] At this time, as shown in Fig. 2(b), since the laser generating devices 1 and 1' and the collimator lenses 2 and 2' are disposed so that a height difference of a predetermined distance in the sub-scanning direction exists between these by providing a level difference to the base plate 27 to which these are attached, the optical axes of the laser beams are arranged in the sub-scanning direction in parallel with a predetermined interval in the vicinity of the optical axis of the optical system on the side of a polygon mirror 6 of the beam splitter 3 (it is to be noted that, in Fig. 2(b), an interval in the sub-scanning direction set between the optical axes of two laser beams i.e., a predetermined interval in the sub-scanning direction set between the laser generating

devices 1 and 1' and the collimator lenses 2 and 2' is emphasized, and, in practice, the interval therebetween is extremely slight).

[0019] Additionally, since there is a need to insulate the laser generating devices 1 and 1' from each other, an insulating member 30 is interposed between a light source device B on which the laser generating device 1' is mounted and the base plate 27 in the first embodiment. Herein, the light source devices A and B have the laser generating devices 1 and 1' and the collimator lenses 2 and 2', respectively, and are made of metal and are electrically conductive, because members that hold those are required to have high accuracy.

[0020] Herein, in order to raise efficiency in using the laser beams to form images, it is preferable to increase the reflectance of a laser beam from the laser generating device 1 that is made incident in the beam splitter 3 and the permeability of a laser beam from the laser generating device 1'. To do so, if a structure is formed in which the laser generating devices 1 and 1' are constructed to emit linearly polarized laser beams, in which a polarizing beam splitter is used as the beam splitter 3, and in which a laser beam emitted from the laser generating device 1 is made incident as s-polarized light on an interference film 3a provided in the beam

splitter 3 whereas a laser beam emitted from the semiconductor laser 1' is made incident as p-polarized light thereon, the reflectance of a laser beam from the laser generating device 1 on the surface of the interference film 3a and the permeability of a laser beam from the laser generating device 1' therethrough can be efficiently increased.

[0021] At this time, the cross-section of the laser beam becomes elliptic since a laser diode generally has a difference in the expansion angle of a laser beam between a polarizing direction and a direction perpendicular thereto. However, in this embodiment, since the optical system from the beam splitter 3 to a to-be-scanned surface is shared between the two laser beams, the longer direction of the cross-section of the laser beam and the shorter direction thereof need to coincide with each other. Therefore, a half-wave plate or an optical member, such as a rotator, that rotates a polarization plane of a laser beam by 90° must be inserted between the collimator lens 2 and the beam splitter 3 or between the collimator lens 2' and the beam splitters 3 in accordance with the polarizing direction of the two laser beams emitted from the laser generating devices 1 and 1'.

[0022] Fig. 3(a) and Fig. 3(b) show the polarizing direction of the two linearly polarized laser beams and the arrangement

of the half-wave plate 14 that is inserted between the beam splitter 3 and the laser generating device 1 or 1' in accordance therewith. In Fig. 3, an x-axis and a y-axis are set in the respective directions in which the two laser beams emitted from the laser generating devices 1 and 1' are propagated, and a z-axis is set in the direction perpendicular to an x-y plane. A polarization beam splitter is used as the beam splitter 3.

[0023] In Fig. 3(a), the laser beams immediately after being emitted from the laser generating devices 1 and 1' both have the x-y plane serving as a polarization plane. When the laser generating devices 1 and 1' are oriented in this way, if this state remains, the two laser beams will both be made incident as p-polarized light on the interference film 3a provided in the beam splitter 3 although the incident directions thereof differ from each other, and the reflectance of the laser beam emitted from the laser generating device 1 will reach an extremely small value.

[0024] Therefore, by inserting the half-wave plate 14 between the beam splitter 3 and the collimator lens 2, the polarization plane of the laser beam emitted from the laser generating device 1 is rotated by 90° so as to be an x-z plane. As a result, the reflectance of the laser beam emitted from the laser generating device 1 in the beam splitter 3 can be efficiently increased.

[0025] On the other hand, in Fig. 3(b), the laser beams immediately after being emitted from the laser generating devices 1 and 1' use the x-z plane and the y-z plane, respectively, as polarization planes. When the laser generating devices 1 and 1' are oriented in this way, if this state remains, the two laser beams will both be made incident as s-polarized light on the interference film 3a provided in the beam splitter 3, and the permeability of the laser beam emitted from the semiconductor element 1' will become extremely small. Therefore, in order to cause the polarization plane to coincide with the x-y plane by rotating the polarization plane of the laser beam by 90°, the half-wave plate 14 is inserted between the beam splitter 3 and the collimator lens 2' so as to increase the permeability thereof in the beam splitter 3.

[0026] Referring back to Fig. 1, a description will be continued. Two laser beams, which pass through the beam splitter 3 and in which the optical axes thereof make a predetermined interval in the sub-scanning direction in the vicinity of the optical axis of the optical system and are arranged in parallel with the optical axis of the optical system, are commonly and temporarily condensed in the sub-scanning direction in the vicinity of a deflection plane of the polygon mirror 6 by a

first cylindrical lens group 12 consisting of two cylindrical lenses 4 and 5. Herein, the cylindrical lenses 4 and 5 have positive power and negative power, respectively, only in the sub-scanning direction, and, by a combination of these, the first cylindrical lens group 12 has positive power only in the sub-scanning direction.

[0027] Therefore, since the laser beams are not condensed in the main scanning direction, the cross-sections of the two laser beams assume the shapes of two lines having their lengths in the main scanning direction in the vicinity of the deflection plane of the polygon mirror 6. The action of the first cylindrical lens group 12 is to perform surface-inclination correction of the deflection plane of the polygon mirror 6 in cooperation with a second cylindrical lens group having positive power in the sub-scanning direction described later.

[0028] Fig. 4 is a partially enlarged view showing the cylindrical lenses 4 and 5, a lens barrel 15 that contains those, and a pedestal 16 that fixes and supports the lens barrel 15 and that is attached to the mounting base plate 9, which have been taken out. In this figure, (a) is a front view, (b) is a sectional view seen from the side, and (c) is a top view. The lens barrel 15 is made up of an inner member 15b to which the cylindrical lens 4 is attached and an outer member 15a to

which the cylindrical lens 5 is attached and to which the inner member 15b is fitted.

[0029] The pedestal 16 is shaped like a substantially rectangular parallelepiped and has a V-groove 16a, whose surface is parallel to an optical axis, formed on its surface. The cylindrical lens barrel 15, which is shaped substantially cylindrically as a whole, is supported in the state of being in contact with both slopes of the V-groove 16a. The V-groove 16a is formed so that the height in the sub-scanning direction of the generating line of the cylindrical lens 5 coincides with the height of the optical axis in the state of supporting the lens barrel 15. The lens barrel 15 is fixed so as not to move with respect to the pedestal 16 by being pressed down by a leaf spring 21 and being fastened by a screw 22.

[0030] The cylindrical lens 5 is pressingly fixed by leaf springs 17 and 18 to an end face, to which the inner member 15b is not fitted, of the outer member 15a of the lens barrel 15. The leaf springs 17 and 18 are fastened to the outer member 15a by screws 19 and 20, respectively. A flat part 15c parallel to a main scanning surface is formed at a location facing the end face of the outer member 15a, and the cylinder generating line can be caused to coincide with the height in the sub-scanning direction of the optical axis by bringing an edge

surface parallel to the cylinder generating line of the cylindrical lens 5 into contact with the flat part 15c.

[0031] In the inner member 15b of the lens barrel 15, a part of its sidewall is protruded on the side where it is not inserted in the outer member 15a, and a flat part 15d parallel to the main scanning surface is formed on a surface on the optical-axis side of the protruded part. The cylindrical lens 4 is fixedly adhered to the end face on the side where it is not inserted in the outer member 15a while the edge surface parallel to the cylinder generating line is brought into contact with the flat part 15d so as to cause the cylinder generating line thereof to coincide with the height in the sub-scanning direction of the optical axis.

[0032] The cylindrical lenses 4 and 5 are adjusted as follows. First, the cylindrical lenses 4 and 5 are attached to the inner member 15b and the outer member 15a of lens barrel 15, respectively. Thereafter, the inner member 15b is fitted to the outer member 15a, and both are adjusted while being rotated and moved so that an interval between the cylindrical lenses 4 and 5 and an on-axis surface reaches a predetermined distance and so that the directions of the cylinder generating lines become the same, and are then fixed so as to be made as a lens block.

[0033] On the other hand, the pedestal 16 is adjusted so as to cause the central line of the V-groove 16a to coincide substantially with the optical axis of the main device, and is attached to the mounting base plate 9. The centers of the optical axes can coincide with each other merely by mounting the lens block, which has undergone an optical adjustment, on the pedestal 16. Lastly, the position of the lens block is adjusted, i.e., a distance in the optical-axis direction to other optical elements, such as a light source, and the direction of the cylinder generating line are adjusted, and the lens block is fixed by the leaf spring 21. This operation makes it possible to position the cylindrical lenses 4 and 5 with ease and with high accuracy.

[0034] Referring again to Fig. 1, a description will be given. The two laser beams temporarily condensed in the sub-scanning direction in the vicinity of the deflection surface of the polygon mirror 6 by the first cylindrical lens group 12 are simultaneously deflected in the main scanning direction of a to-be-scanned surface by the rotation of the deflection surface of the polygon mirror 6. The polygon mirror 6 is shaped like a regular polygonal pillar in which many (six in Fig. 1) reflective surfaces parallel to the rotational axis 6a thereof are formed as deflection surfaces, and is rotated around the

rotational axis 6a at a constant and high speed while being driven by a motor (not shown) attached to the backface of the mounting base plate 9.

[0035] The polygon mirror 6 is contained in a cover (not shown) for keeping dust away, and the two laser beams that have been made incident on the deflection surface of the polygon mirror 6 or that have been deflected pass through a glass window 14 provided at the side face of the cover.

[0036] The two laser beams that have been deflected by the deflection surface of the polygon mirror 6 are condensed in the main scanning direction by a scanning lens group 13 that consists of two lenses 7 and 8 and that has positive power in the main scanning direction as a whole. Further, the two laser beams are condensed in the sub-scanning direction by a second cylindrical lens group (not shown) that is disposed between the scanning lens group 13 and the to-be-scanned surface (not shown) and that has positive power in the sub-scanning direction.

[0037] Accordingly, the two laser beams are imaged as two spots that are apart from each other by a predetermined distance in the sub-scanning direction on the to-be-scanned surface, and, in accordance with the rotation of the polygon mirror 6, scanning is performed in the main scanning direction so as to

simultaneously produce two parallel scanning lines that are apart from each other by a predetermined distance in the sub-scanning direction. Scanning in the sub-scanning direction is performed by allowing the to-be-scanned surface to move.

[0038] In this embodiment, the scanning lens group 13 consisting of the two lenses 7 and 8 is designed to constitute an  $f\theta$  lens that has power only in the main scanning direction as a whole. Since the angular velocity of the deflection angle of the two laser beams deflected by the deflection surface of the polygon mirror 6 is made constant by allowing the deflection surface of the polygon mirror 6 to rotate at equal angular velocity, the use of the  $f\theta$  lens makes it possible for the two laser beams to scan the to-be-scanned surface at constant speed in the main scanning direction.

[0039] The structure made up of the scanning lens group 13 forming the  $f\theta$  lens in the main scanning direction as a whole and the second cylindrical lens group having positive power in the sub-scanning direction can be replaced with a toroidal lens that has different power between the main scanning direction and the sub-scanning direction or can be replaced with an aspherical lens.

[0040] In the aforementioned structure, it is possible to write

two scanning lines onto the to-be-scanned surface simultaneously and in parallel by using two laser beams emitted from the two laser generating devices 1 and 1', and the scanning lines written at that time can be arranged in several ways as shown in Fig. 5.

[0041] In a case shown in Fig. 5(a), if two scanning lines are simultaneously written while the line pitch of the scanning line is being kept as in a case where one laser beam is used, image formation can be performed at higher speed than in the case where one laser beam is used. That is, in the first main scanning, scanning lines  $L_{11}$  and  $L_{21}$  are simultaneously written with a predetermined line pitch, and, in the second main scanning, scanning lines  $L_{12}$  and  $L_{22}$  are simultaneously formed so that a distance between the scanning line  $L_{12}$  and the scanning line  $L_{21}$  formed the first time becomes equal to the predetermined line pitch, and the third and subsequent main scanning operations are performed in the same way. In this case, the to-be-scanned surface is moved in the sub-scanning direction twice as fast as in the case in which one laser beam is used, and the image formation speed can be doubled.

[0042] Likewise, in the case of Fig. 5(b), scanning is performed with two laser beams simultaneously and in parallel while the line pitch of the scanning line is being kept as in the case

where one laser beam is used. However, differing from the case of Fig. 5(a), the sub-scanning speed in this case is set at the same value as in the case where one laser beam is used. Thus, one scanning line is successively and repeatedly scanned with two laser beams in such a way that the scanning line  $L_{21}$  at the first time is superposed on the scanning line  $L_{12}$  at the second time, and the scanning line  $L_{22}$  at the second time is superposed on the scanning line  $L_{13}$  at the third time, and the density of images formed on the to-be-scanned surface can be increased.

[0043] Moreover, in both cases shown in Figs. 5(a) and 5(b), if the relative position of two parallel scanning lines scanned simultaneously with two laser beams on a to-be-scanned surface deviates in the main scanning direction or in the sub-scanning direction, irregularity in the main scanning direction will occur at the writing position of the scanning line, or irregularity in pitch of the scanning line will occur in the sub-scanning direction.

[0044] Therefore, the size of each of the optical components that constitute the scanning optical system or the relative position among these must be maintained with high accuracy, and especially the position accuracy among the light source device A made up of the laser generating device 1 and the

collimator lens 2, etc., the light source device B made up of the laser generating device 1', the collimator lens 2', etc., and the beam splitter 3 must be determined with high accuracy since error sensitivity is very high to the relative position of two spots formed on the to-be-scanned surface by laser beams.

[0045] Therefore, in the part shown in Fig. 2, members that constitute the light source devices A and B, i.e., laser holding members 101 and 101' that hold the laser generating devices 1 and 1', lens barrels 104 and 104' to which the collimator lenses 2 and 2' are mounted, lens barrel holding members 102 and 102' that hold the lens barrels 104 and 104', the base plate 27 to which the light source devices A, B and the beam splitter 3 are attached, etc., are made of metal.

[0046] On the other hand, in both the laser generating devices 1 and 1', positive power-supply voltage is applied to a housing that has electric conductivity, but, since there is a need to individually adjust the emission intensity of both, the respective power-supply voltages do not always have the same value, and, since there is a need to cut off a noise transmitted from one of the electric power sources to the other electric power source, both must be insulated from each other.

[0047] However, when the insulating members 305 and 305' are interposed between the laser generating device 1 and the

collimator lens 303 and between the laser generating device 1' and the collimator lens 303' as in the prior art shown in Fig. 11, the insulating members 305 and 305' undergo thermal strain caused by the heat generation of the laser generating devices 1 and 1' and undergo deformation caused by an external force, and thus, even when only slight positional deviation occurs in the laser generating devices 1 and 1' in planes perpendicular to the optical axes of the collimator lenses 303 and 303', laser beams that have passed through the collimator lenses 303 and 303' and that have been emitted from the beam splitter 304 vary in slant. As a result, the error caused at the relative position of two spots formed on the to-be-scanned surface by the two laser beams becomes large.

[0048] A possible way to deal with this defect is to form a block of the light source devices A and B and insulate either the light source device A or B from the metallic base plate 27, without interposing insulating members between the laser generating devices 1 and 1' and the collimator lenses 2 and 2' as shown in Fig. 2.

[0049] Referring now to Fig. 6 and Fig. 7, a description will be given of how the slant of a laser beam that has been reflected by the interference film 3a of the beam splitter 3 or that has passed therethrough changes if the laser generating device 1

or 1' is displaced because of thermal strain or deformation of the insulating member or if the beam splitter 3 generates a rotational deviation because of thermal deformation, or the like, caused by heat generation of the laser generating devices 1 and 1' when the light source device A or B is insulated from the base plate 27 by interposing an insulating member therebetween.

[0050] Fig. 6 shows an angle at which the propagating directions of two laser beams emitted from the beam splitter 3 are displaced from a predetermined direction when an insulating member is interposed between the light source device A that outputs a laser beam to be reflected by the beam splitter 3 and the base plate 27. At this time, the position of the laser generating device 1 can be displaced with the lapse of time by thermal deformation, or the like, of the insulating member, but, since the laser generating device 1' is attached directly to the base plate 27, the laser generating device 1' is kept at a predetermined position.

[0051] Herein, let it be supposed that the laser generating device 1 is displaced to 1a, and thereby the propagating direction of a laser beam  $LB_{R1}$  emitted from there changes by  $\Delta\theta_1$  from a predetermined direction counterclockwise in a main scanning plane, and, at the same time, the interference film

3a is rotated by  $\Delta\theta_2$  counterclockwise and reaches 3a' (it is to be noted that, since Fig. 7 shows a state in which the  $LB_{R1}$  changes clockwise, its displacement angle is shown as  $-\Delta\theta_1$  in the figure). At this time, the propagating direction of the laser beam  $LB_{T1}$  emitted from the laser generating device 1' does not change. Then, in the interference film 3a, a displacement angle in the propagating direction from a predetermined direction of transmitted light  $LB_{T2}$  by the permeation of the laser beam  $LB_{T1}$  and a displacement angle in the propagating direction from a predetermined direction of reflected light  $LB_{R2}$  by the reflection of the laser beam  $LB_{R1}$  are expressed as follows:

(Displacement angle in the propagating direction of transmitted light  $LB_{T2}$ )=0 ..... (1)

(Displacement angle in the propagating direction of reflected light  $LB_{R2}$ )= $2 \cdot \Delta\theta_2 - \Delta\theta_1$  ..... (2)

[0052] On the other hand, Fig. 7 shows an angle at which the propagating directions of two laser beams emitted from the beam splitter 3 displace from a predetermined direction when an insulating member is interposed between the light source device B, which outputs a laser beam that permeates the beam splitter 3, and the base plate 27. At this time, although the position of the laser generating device 1' can be displaced with the

lapse of time, the laser generating device 1 is kept at a predetermined position.

[0053] Herein, let it be supposed that the laser generating device 1' is displaced to 1'a, and thereby the propagating direction of the laser beam  $LB_{T1}$  emitted from there changes by  $\Delta\theta_1$  counterclockwise in the main scanning plane, and, at the same time, the interference film 3a is rotated by  $\Delta\theta_2$ , counterclockwise and reaches 3a'. At this time, the propagating direction of the laser beam  $LB_{R1}$  emitted from the laser generating device 1 does not change. Then, in the interference film 3a, the propagating direction of transmitted light  $LB_{T2}$  by the permeation of the laser beam  $LB_{T1}$  and the propagating direction of reflected light  $LB_{R2}$  by the reflection of the laser beam  $LB_{R1}$  change from a predetermined direction, and those displacement angles are expressed as follows:

(Displacement angle in the propagating direction  
of transmitted light  $LB_{T2}$ ) =  $\Delta\theta_1$  ..... (3)

(Displacement angle in the propagating direction  
of reflected light  $LB_{R2}$ ) =  $2 \cdot \Delta\theta_2$  ..... (4)

[0054] Thus, a displacement angle from a predetermined direction in the propagating direction of each of transmitted light  $LB_{T2}$  and reflected light  $LB_{R2}$  differs between a case in which an insulating member is interposed between the light

source device A and the base plate 27 and a case in which an insulating member is interposed between the light source device B and the base plate 27. Since  $\Delta\theta_1$  and  $\Delta\theta_2$  can both take either a positive value or a negative value, the maximum value of the displacement angle is given by Equation (2) from Equations (1) to (4). In other words, a displacement from a predetermined direction of the propagation direction of a laser beam emitted from the beam splitter 3 becomes greater in a case in which an insulating member is interposed between the light source device A, which outputs a laser beam that is reflected by the beam splitter 3, and the base plate 27 than in the other case. [0055] Herein, a description has been given of a case in which the propagating direction of the laser beam  $LB_{R1}$  or  $LB_{T1}$  emitted from the laser generating device 1 or 1' and the direction of the interference film 3a of the beam splitter 3 change from a predetermined direction in the main scanning plane by interposing an insulating member between the light source device A or B and the base plate 27. However, likewise, even when displacement occurs in the sub-scanning direction, the displacement of the propagation direction of a laser beam emitted from the beam splitter 3 becomes greater in a case in which an insulating member is interposed between the light source device A, which outputs a laser beam that is reflected

by the beam splitter 3, and the base plate 27 than in the other case.

[0056] From this, in the first embodiment, the insulating member 30 formed of a polystyrene-made sheet member is interposed between the light source device B, which includes the laser generating device 1' and which outputs a laser beam that permeates the beam splitter 3, and the base plate 27, and both are attached by use of the resin screw 31 as shown in Fig. 2, in order to restrict the displacement in the propagating direction of a laser beam emitted from the beam splitter 3 to a small displacement. Polyacetal, polyvinyl chloride, etc., can be used as a material of the insulating member 30. Additionally, the light source device A, which includes the laser generating device 1 and which emits a laser beam that is reflected by the beam splitter 3, is attached directly to the base plate 27.

[0057] According to this structure, even when the insulating member 30 is deformed, the displacement in the propagating direction of a laser beam, which passes through the collimator lens 2 and which is emitted from the beam splitter 3, becomes smaller than in the case of the prior art shown in Fig. 11 by interposing the insulating member 30 between the light source device B, which has the laser generating device 1' and the

collimator lens 2' that are used as a block, and the base plate 27. Moreover, the displacement in the propagating direction of a laser beam emitted from the beam splitter 3 can be restricted to a smaller displacement by interposing the insulating member 30 not between the light source device A, which emits a laser beam that is reflected by the beam splitter 3, and the base plate 27 but between the light source device B, which emits a laser beam that permeates the beam splitter 3, and the base plate 27.

[0058] Additionally, since the insulating member 30 is merely pressed from both sides to the light source device B and to the base plate 27, a problem regarding mechanical strength does not arise even if its thickness is made extremely small (for example, about tens of  $\mu\text{m}$ ), and, even if the insulating member 30 is deformed, the absolute value of its deformation amount also becomes small in that case. Therefore, the positional deviation of the light source device B also becomes small, and, as a result, the displacement in the propagating direction of a laser beam emitted from the beam splitter 3 can be reduced even more.

[0059] Fig. 8 is a partially enlarged view showing the light source devices A and B, the beam splitter 3, the base plate 27 to which these are attached, the insulating member 30

interposed between the light source device B and the base plate 27, which are taken out, according to a second embodiment. In this figure, (a) and (b) are a top view and a side view, respectively, of this part. The same constituent elements as in the first embodiment shown in Fig. 2 are given to the same reference characters, and a description thereof is omitted.

[0060] Likewise, in the second embodiment, the light source device B, which includes the laser generating device 1' and which emits a laser beam that permeates the beam splitter 3, is provided with the insulating member 30, and is attached to the base plate 27 by use of the resin screw 31. The same material as in the first embodiment can be used as a material of the insulating member 30. Additionally, the light source device A, which includes the laser generating device 1 and which emits a laser beam that is reflected by the beam splitter 3, is attached directly to the base plate 27.

[0061] According to this structure, as in the first embodiment, even when the insulating member 30 is deformed, the displacement in the propagating direction of a laser beam, which passes through the collimator lens 2 and which is emitted from the beam splitter 3, becomes smaller than in the case of the prior art shown in Fig. 11. Moreover, the displacement in the propagating direction of a laser beam emitted from the

beam splitter 3 can be restricted to a smaller displacement by interposing the insulating member 30 not between the light source device A, which emits a laser beam that is reflected by the beam splitter 3, and the base plate 27 but between the light source device B, which emits a laser beam that permeates the beam splitter 3, and the base plate 27.

[0062] Additionally, as in the first embodiment, the thickness of the insulating member 30 can be made extremely small without causing a problem regarding mechanical strength, and, even if the insulating member 30 is deformed, the absolute value of its deformation amount also becomes small in that case. Therefore, the positional deviation of the light source device B also becomes small, and, as a result, the displacement in the propagating direction of a laser beam emitted from the beam splitter 3 can be reduced even more.

[0063]

[Effects of the Invention] According to the present invention, the laser diodes of first and second laser generating devices are electrically isolated from each other by insulating members, for example, when the apparatus is used in such a way that an anode of the laser diode is connected to an electroconductive housing, and power-supply voltage is received by the anode through the housing from the outside, and therefore,

predetermined power-supply voltages can be given so as to correct the characteristic variability of the laser diode, and the influence of noise between both can be mutually cut off. Moreover, since the insulating member to be interposed for insulation is provided to the side of the second laser generating device, the displacement in the propagating direction of a laser beam caused by the interposition of the insulating member can be restricted to be small, and, as a result, the relative-position error of two spots formed on a to-be-scanned surface by the two laser beams becomes small, and therefore an excellent image quality can be obtained.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] Top view of a multi-beam scanning optical apparatus according to a first embodiment of the present invention.

[Fig. 2] Partially enlarged view showing a structure of laser generating devices, collimator lenses, a beam splitter, and a base plate to which these are attached, which are mounted to the multi-beam scanning optical apparatus of Fig. 1.

[Fig. 3] Schematic arrangement view of a light source part of the multi-beam scanning optical apparatus of Fig. 1 when a polarization beam splitter and a half-wave plate are used in the light source part.

[Fig. 4] Partially enlarged view showing a structure of a first

cylindrical lens group and the like mounted to the multi-beam scanning optical apparatus of Fig. 1.

[Fig. 5] View showing an array of scanning lines when scanning is performed by use of two laser beams.

[Fig. 6] View showing an angle at which two laser beams emitted from the beam splitter are displaced from a predetermined direction because of deformation of the insulating member and because of displacement of the beam splitter when an insulating member is interposed between a light source device, which emits a laser beam that is reflected by the beam splitter, and a base plate.

[Fig. 7] View showing an angle at which two laser beams emitted from the beam splitter are displaced from a predetermined direction because of deformation of the insulating member and because of displacement of the beam splitter when an insulating member is interposed between a light source device, which emits a laser beam that permeates the beam splitter, and a base plate.

[Fig. 8] Partially enlarged view showing light source devices, a beam splitter, a base plate to which these are attached, an insulating member 30 according to a second embodiment of the present invention, which are taken out.

[Fig. 9] View showing an example of internal wiring of a laser generating device.

[Fig. 10] View showing a structure when the laser generating device of Fig. 9 is disposed in the multi-beam scanning optical apparatus.

[Fig. 11] Partially enlarged view showing light source devices, a beam splitter, a base plate to which these are attached, an insulating member 30 of a conventional multi-beam scanning optical apparatus, which are taken out.

[Description of Symbols]

1,1' Laser generating device

2,2' Collimator lens

3 Beam splitter

3a Interference film

4,5 Cylindrical lens

6 Polygon mirror

6a Rotational axis

9 Mounting base plate

10 Screw

11 Counterbored hole

12 First cylindrical lens group

13 Scanning lens group

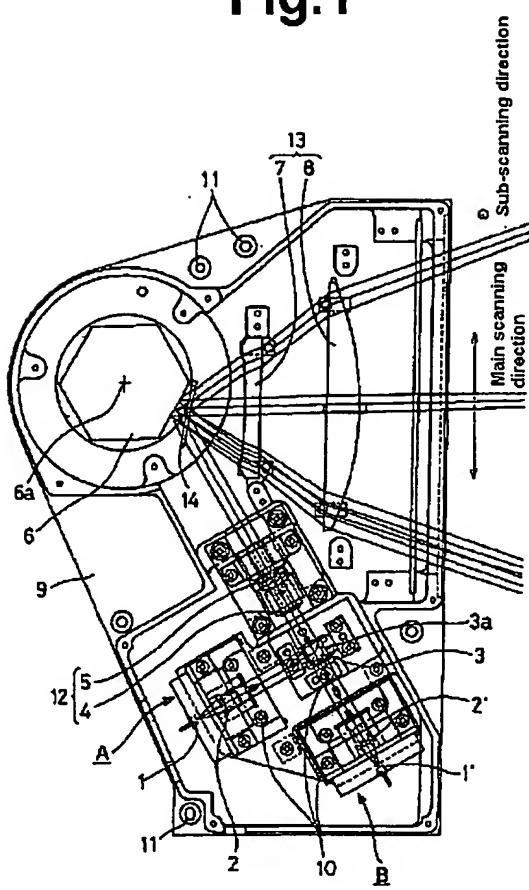
14 Half-wave plate

15 Lens barrel

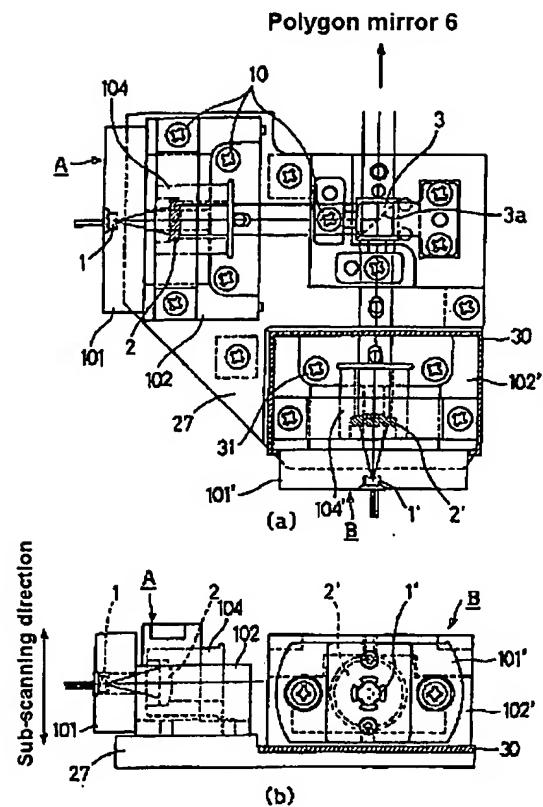
15a Outer member

15b Inner member  
15c,15d Flat part  
16 Pedestal  
16a V-groove  
17,18 Leaf spring  
19,20 Screw  
21 Leaf spring  
22 Screw  
27 Base plate  
30 Insulating member  
31 Resin screw  
101,101' Laser holding member  
102,102' Lens barrel holding member  
104,104' Lens barrel  
A,B Light source device

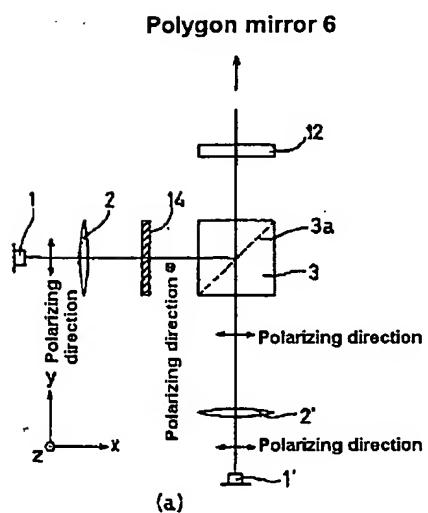
**Fig.1**



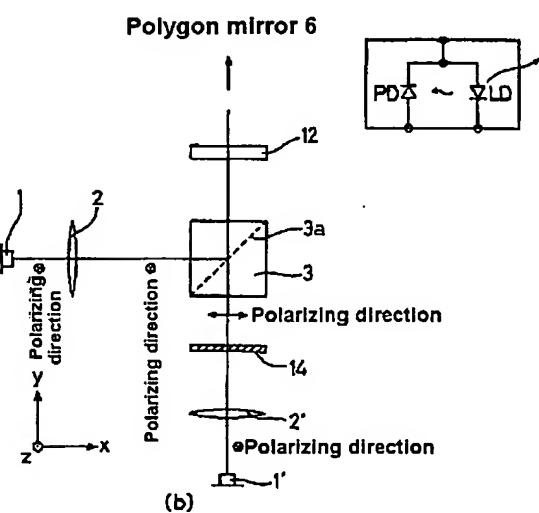
**Fig.2**



**Fig.3**

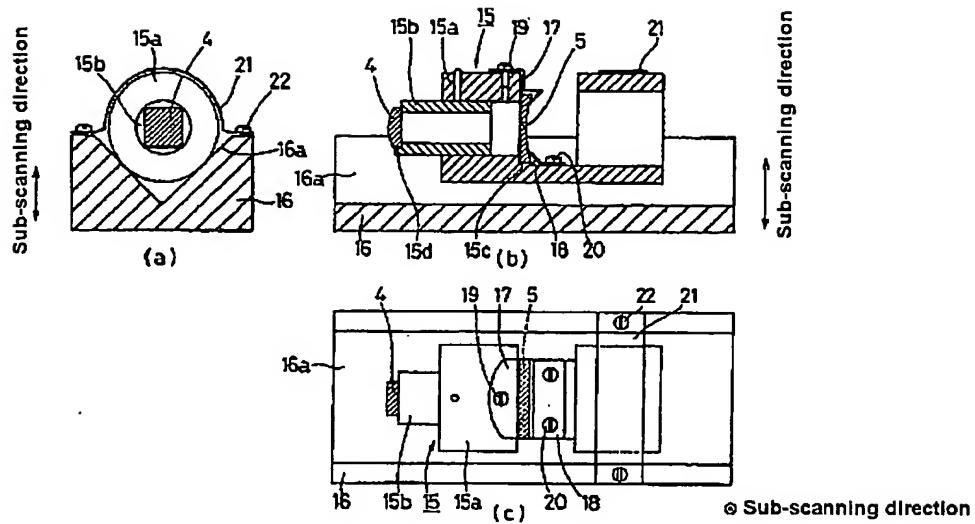


**Polygon mirror 6**

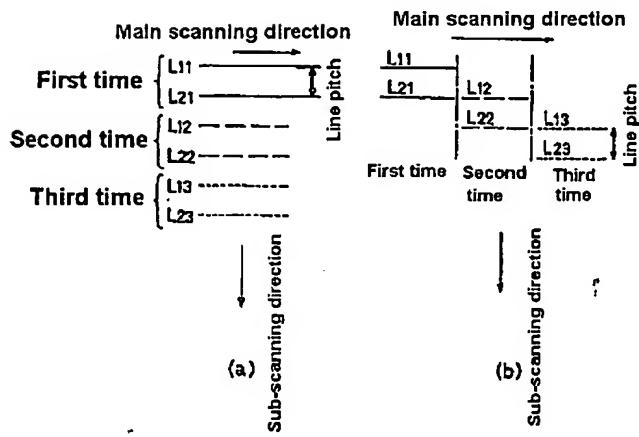


**Fig.9**

## Fig.4



## Fig.5



## Fig10

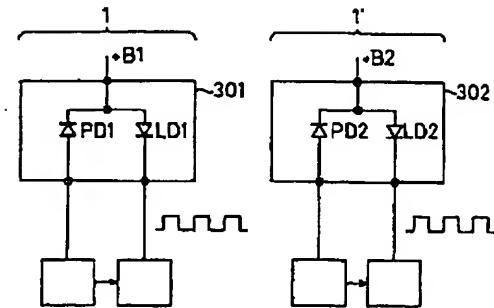


Fig.6

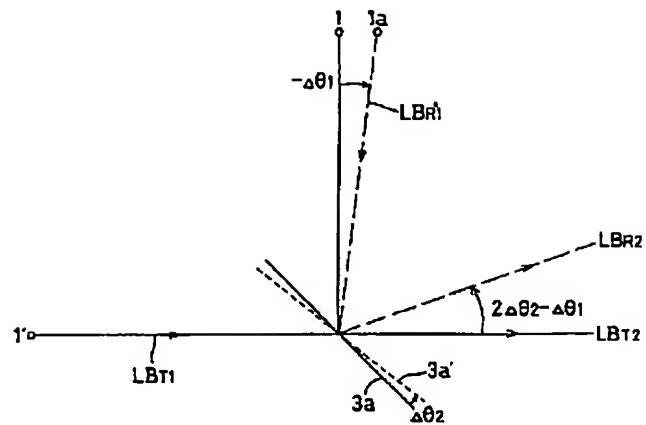
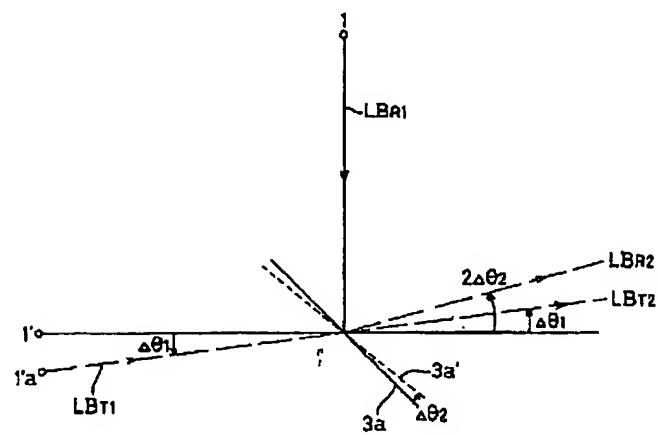
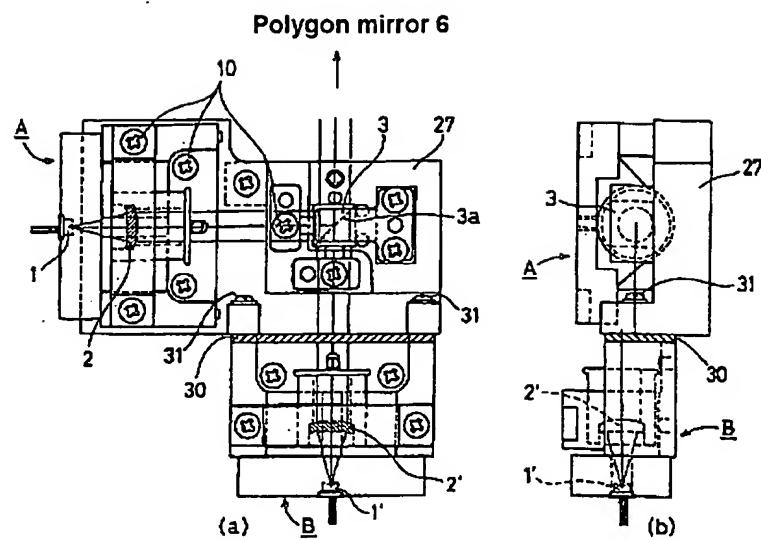


Fig.7



## Fig.8



## Fig.11

